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(56) Documents Cited
GB 2230088 A GB 2230087 A GB 2080947 A
GB 0809364 A GB 0732058 A GB 0672758 A
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(58) Field of Search
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INT CL[5] G01J
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(54) **Broadband radiometer**

(57) A broadband radiometer (20) comprises a housing (12), means (4) for dispersing radiation from a radiation source (6) into spatially separated component parts of different wavelengths, entrance means (8) for enabling the radiation to enter the housing (12), exit means for enabling radiation to leave the housing (12), a rotatable obturator (22) for blocking the path of the radiation, at least one curved slot (26) in the obturator (22), an aperture (24) which is positioned for registering with the slot (26) and which forms either the entrance means (8) as shown or the exit means (figures 4 and 5), and detector means (14) for detecting radiation passing through the slot (26) and the aperture (24). Two spectral regions may be scanned simultaneously by means of a single rotating obturator with two slots and two radiation paths having dispersing means covering different spectral regions.

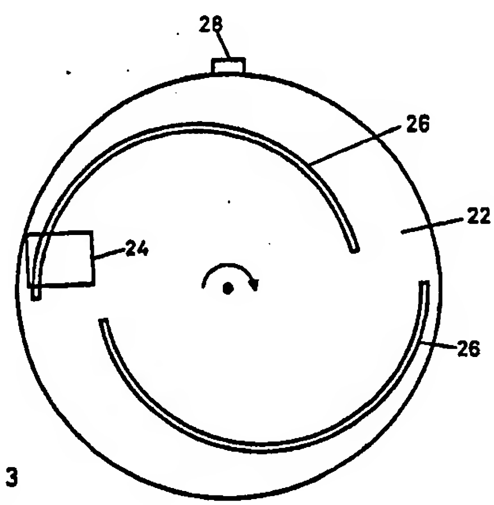

Fig. 3

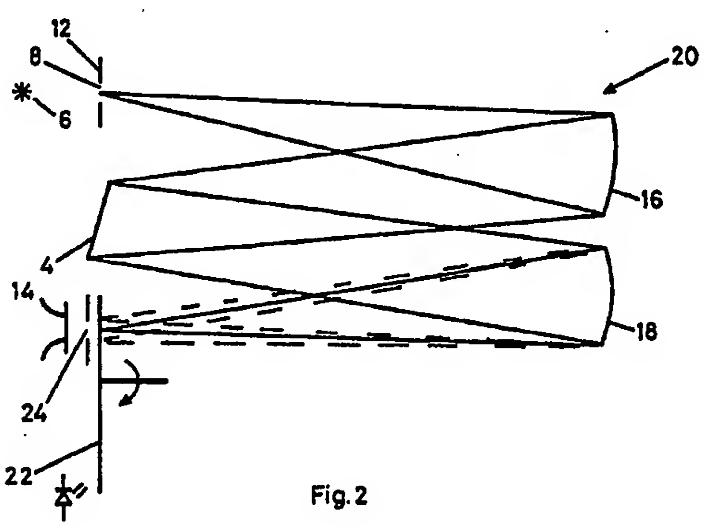

Fig. 2

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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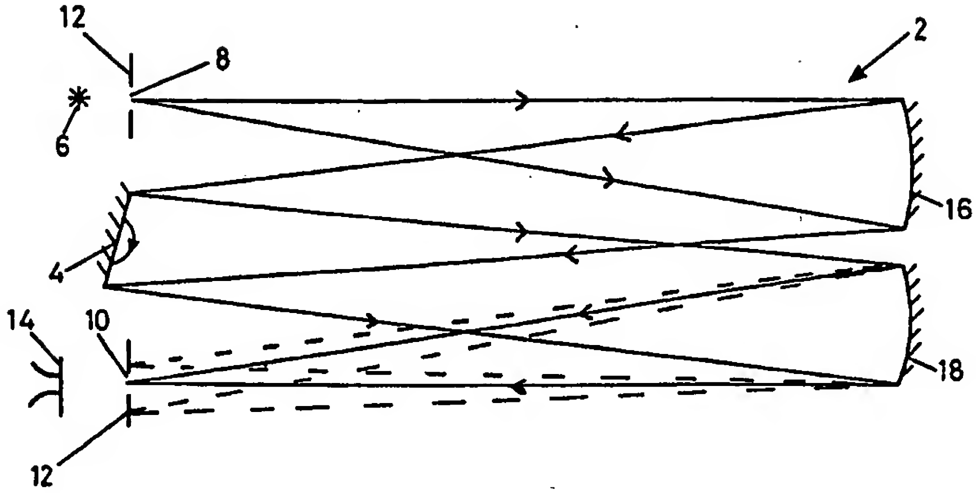

Fig.1

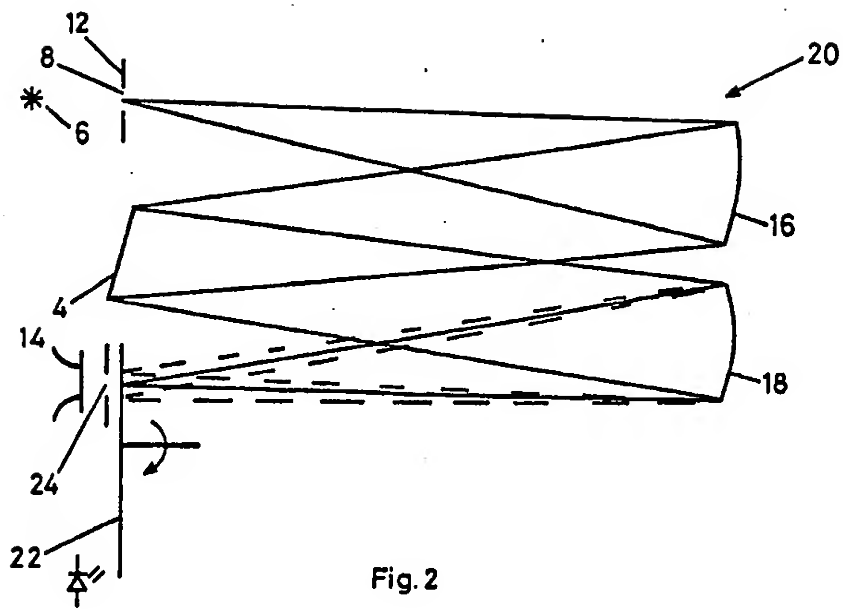

Fig. 2

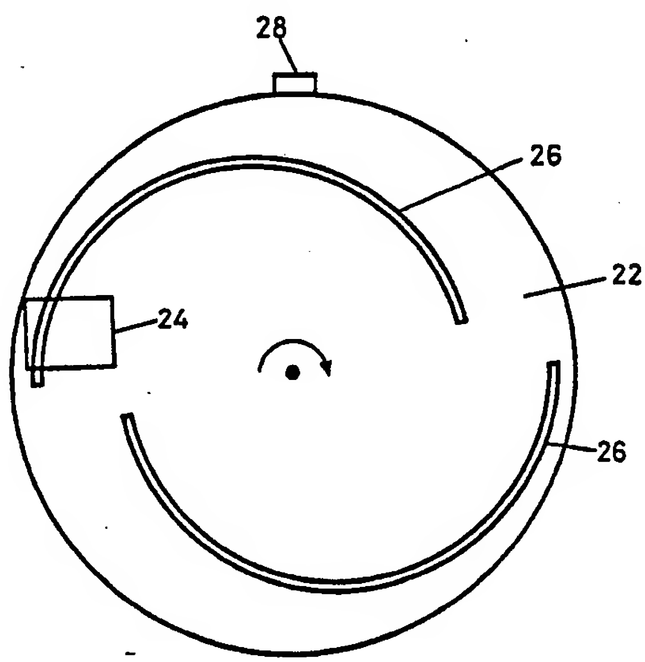

Fig. 3

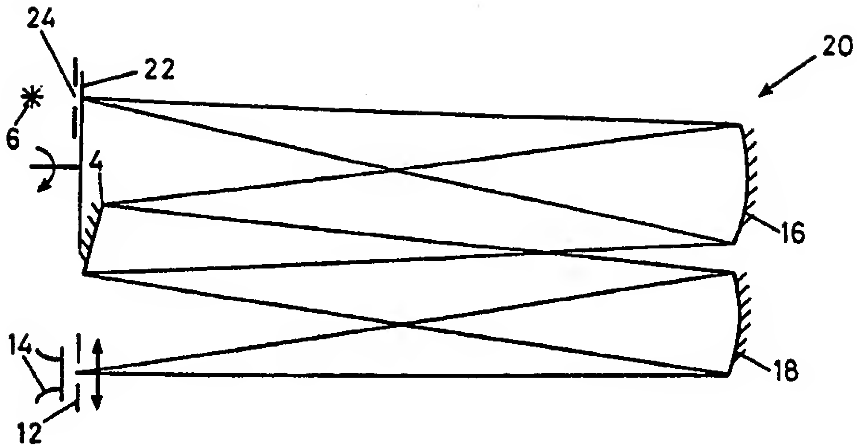

Fig. 4

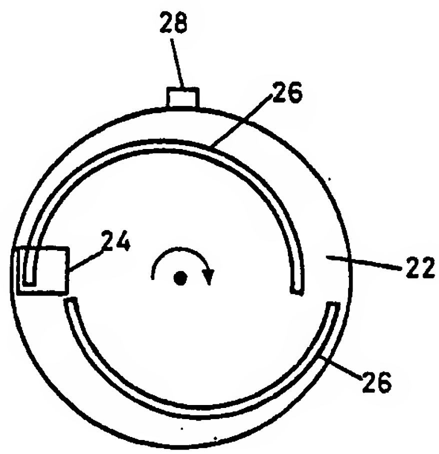

Fig.5

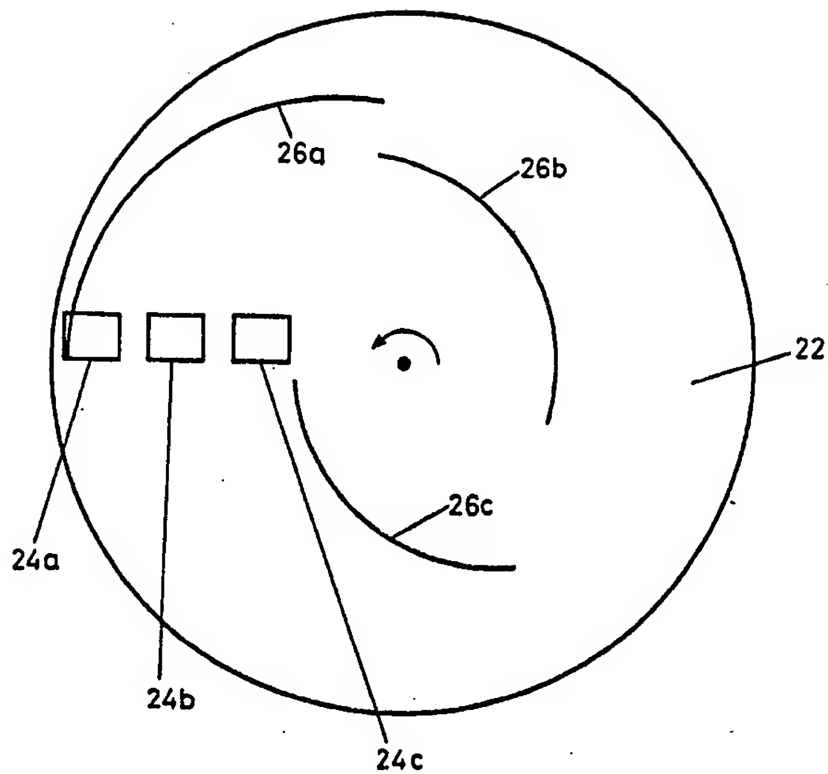

Fig. 6

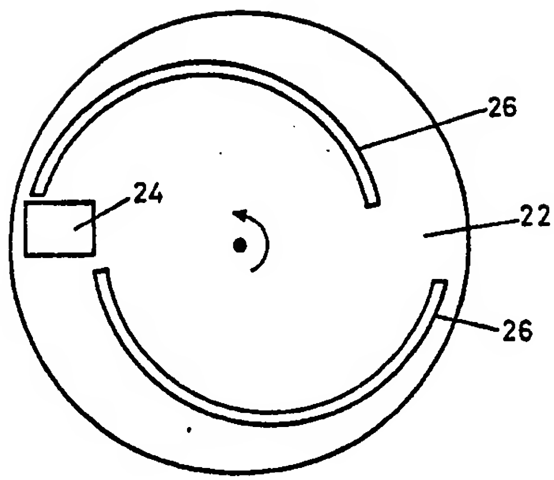

Fig.7

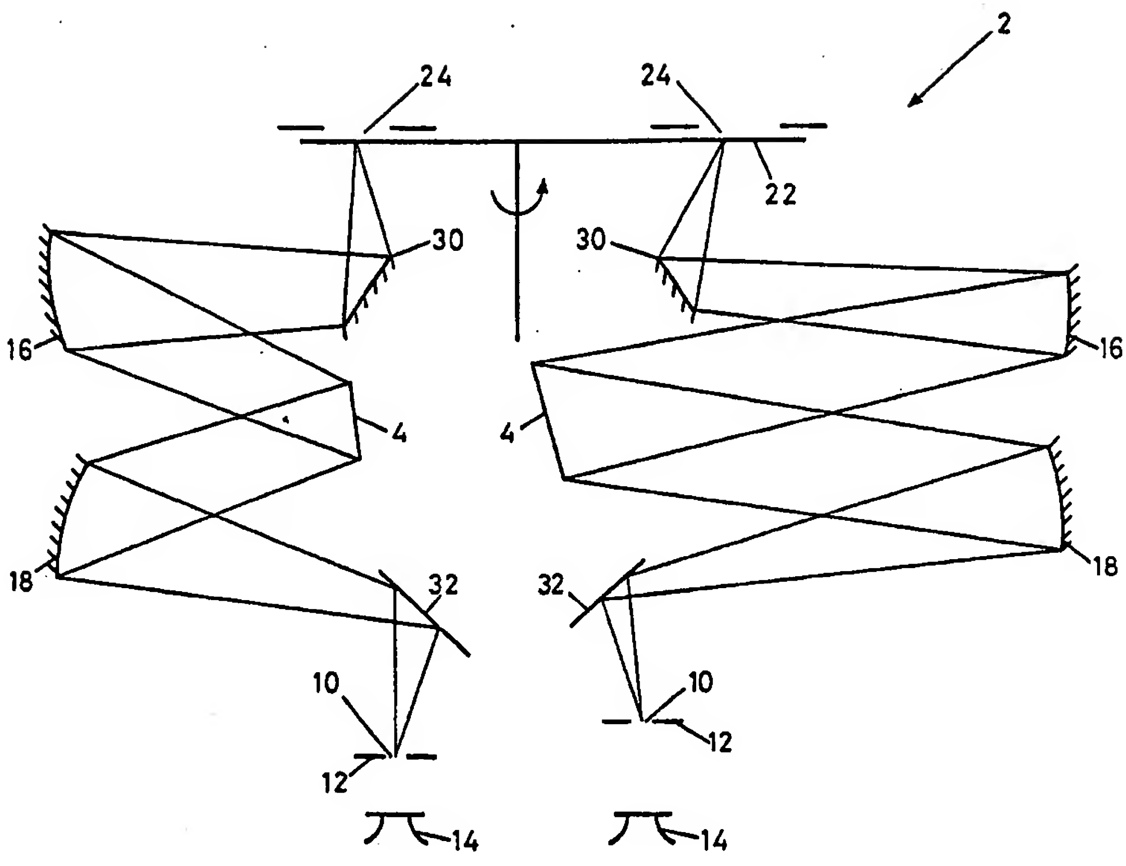

Fig.8

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A BROADBAND RADIOMETER

This invention relates to a broadband radiometer.

Monochromators are well known. A monochromator is an instrument for selecting radiation with a narrow spectral bandwidth from a broad band or continuous spectral source. The monochromator has an entrance slit in a housing and the source falls on the entrance slit. The illuminated slit is imaged via a dispersing optical component, for example a diffraction grating or prism, so that radiation at different wavelengths is spacially separated in the image plane. Radiation of a particular narrow spectral region is then isolated with an exit slit that blocks the radiation at other wavelengths. The wavelength and spectral bandwidth of the radiation leaving the exit slit is set by the parameters of the dispersing and imaging optical components, and the widths of the entrance and exit slits.

The monochromators are usually designed so that they can be scanned to select narrow spectral bandwidth radiation over a continuously variable wavelength. Scanning is normally achieved by rotating the dispersing optical component which moves the spectrally dispersed image of the entrance slit across the exit slit so that the exit slit selects a different part of the spectrum. Other instruments called spectrographs, or spectrometers,

keep the dispersing optical component in a fixed position and use a photographic plate, or a linear detector array respectively to replace the exit slit. This makes it possible to record radiation from a range of wavelengths simultaneously. The photographic plate retains the spectral separation of the radiation and the spatial information can be analysed by scanning the recorded image at a later date. The linear detector array effectively measures radiation passing through an array of parallel slits, each recording a different part of the spectrum. The information can be stored or displayed in real time.

The present invention is based upon the discovery that if the wavelength from a monochromator is scanned in a novel way, then a broadband radiometer can be produced.

Accordingly, in one non-limiting embodiment of the present invention there is provided a broadband radiometer comprising a housing, dispersing means for dispersing radiation from a radiation source such that the radiation is spatially separated into component parts of different wavelengths, entrance means for enabling radiation to enter the housing, exit means for enabling the radiation to leave the housing, obturator means which is rotatable and which is for blocking the path of the radiation, at least one slot which is provided in the obturator means, an aperture which is positioned for

registering with the slot and which forms the entrance means or the exit means in dependence upon the position of the obturator means, and detector means for detecting radiation passing through the slot and the aperture.

The broadband radiometer of the present invention provides a low cost high accuracy scanning mechanism. Traditional monochromators which scan wavelengths by rotating the dispersing optical component require a very well engineered and hence very expensive mechanism to ensure accurate knowledge of the position of the dispersing optical component, and hence the wavelength set.

The radiometer may include electrical drive means for driving the obturator means.

The radiometer may be one in which the aperture is positioned at an exit part of the radiometer, whereby the aperture forms the exit means. Alternatively, the radiometer may be one in which the aperture is positioned at an entrance part of the radiometer, whereby the aperture forms the entrance means.

The obturator means may be positioned in front of the aperture. Alternatively, the obturator means may be positioned behind the aperture.

The obturator means is preferably a disc. Other types of obturator means may however be employed. When th obturator means is a disc, then the disc will usually

be rotatable about an axis perpendicular to the plane of the disc.

The radiometer may be one in which the slot is curved. The radiometer may then be one in which at least one of the curvature of the slot and the width of the slot varies along the length of the slot in order to weight different parts of the scanned spectrum differently, the lower the curvature of the slot and/or the wider the slot, the greater the weight given to the part of the spectrum passed by the slot and the aperture. Mechanical means may be employed to change the curvature of the slot and/or the width of the slot such that the radiometer becomes a programmable radiometer.

The slot may be interrupted in order to provide a zero reading during rotation of the obturator means.

There may be two or more of the slots.

The radiometer may include memory means for storing the correct weighting function of the recorded spectral data for the particular application required. The radiometer then becomes a programmable radiometer. The radiometer may be one in which the response of the radiometer is able to be calibrated as a function of wavelength and in which the required weighting of each of the data points in the recorded sequence is then able to be calibrated.

The radiomet r may include an analogue to digital converter.

The entrance means will usually be an entrance slit. Similarly, the exit means will usually be an exit slit.

The dispersing means is preferably a diffraction grating. Other types of dispersing means may however be employed.

The radiometer may include a collimating mirror and a focusing mirror, the collimating mirror and the focusing mirror being for use with the diffraction grating in enabling the radiation to pass from the entrance means to the exit means.

Embodiments of the invention will now be described solely by way of example and with reference to the accompanying drawings in which:

Figure 1 shows schematically a typical known monochromator;

Figure 2 shows schematically a first broadband radiometer of the invention;

Figure 3 is a front view of part of the radiometer shown in Figure 2;

Figure 4 shows schematically a second broadband radiometer;

Figure 5 is a front view of the radiometer shown in Figure 3;

Figure 6 is a front view of part of a third broadband radiometer of the invention;

Figure 7 is a front view of part of a fourth broadband radiometer of the invention; and

Figure 8 shows schematically a fifth broadband radiometer of the invention.

Referring to Figure 1, there is shown a monochromator 2 comprising dispersing means in the form of a diffraction grating 4 for dispersing radiation from a radiation source 6 such that the radiation is spatially separated into component parts of different wavelengths. The monochromator 2 comprises entrance means in the form of an entrance slit 8 for enabling the radiation from the radiation source 6 to enter the monochromator 2. The monochromator 2 also comprises exit means in the form of an exit slit 10 for enabling radiation to leave the monochromator 2. The entrance slit 8 and the exit slit 10 may form part of a housing 12 of the monochromator 2. The monochromator 2 further includes detector means 14 for detecting radiation passing through the exit slit 10. The solid lines and the broken lines shown in Figure 1 illustrate the spatially dispersed spectral image of the entrance slit 8 appearing at the exit slit 10. This spatially dispersed spectral image is provided using the illustrated collimating mirror 16 and the focusing mirror 18 which operate as shown with the diffraction grating 4.

Referring now to Figur s 2 - 8, similar parts as in Figure 1 have been given the same reference numerals for ease of comparison and understanding.

Figure 2 shows a broadband radiometer 20 of the present invention. By comparing Figure 2 with Figure 1, it will be seen that Figure 2 omits the entrance slit 10 of Figure 1. Instead, obturator means in the form of a rotatable disc 22 and an aperture 24 are provided. As can be seen from Figure 3 the disc 22 is provided with two slots 26 which are curved as shown and which register with the aperture 24 as shown. The slots 26 scan across the aperture 24 as the disc 22 rotates. A synchronising pulse is generated by a tab 28 cutting a light emitting diode beam. The disc 22 may be driven by an electrical drive motor (not shown).

It will be appreciated from Figure 2 that the disc 22 and the aperture 24 are positioned at an exit part of the radiometer 20.

The monochromator 2 of Figure 1 operates such that radiation from the radiation source 6 is imaged via the diffraction grating 4 so that radiation at different wavelengths is spatially separated in the image plane. Radiation of a particular narrow spectral region is isolated using the exit slit 10, which blocks the radiation at other non-selected wavelengths. The wavel ngth and the sp ctral bandwidth of the radiation

leaving the exit slit is set by the parameters of the dispersing and imaging optical components, and the width of the entrance slit 8 and the exit slit 10. The monochromator 2 is such that it can be scanned to select narrow spectral radiation over a continuously variable wavelength. Scanning is normally achieved by rotating the diffraction grating 4 which moves the spectrally dispersed image of the entrance slit 8 across the exit slit 10 so that the exit slit 10 selects a different part of the spectrum. In contrast and referring to Figure 2, it will be seen that the radiometer 20 effects scanning of the wavelength using the rotatable disc 22. The aperture 24 replaces the exit slit 10 of the monochromator 2 and the disc 22 is shown as rotating in front of the aperture 24. In alternative embodiment of the invention, the disc 22 can rotate behind the aperture 24.

In the radiometer 20, the two slots 26 are formed in the disc in such a way that the slots 26 move repeatedly across the image of the entrance slit 8 as the disc 22 is rotated. The disc rotation speed is accurately controlled to produce an even and constant rate. This is partly achieved by electrical control of the electrical drive motor driving the disc 22, and it partly occurs automatically because of the movement of inertia of the disc 22 itself. In alternativ mbodiments of the

invention, the radiometer 20 may have one slot 26 or more than two slots 26.

The radiometer 20 is such that the detector 14 is mounted behind the disc 22 so that radiation passing through the aperture 24 and the appropriate registering slot 26 falls on the detector 14. The output of the detector 14 is then observed in real time. By synchronising the output of the detector 14 with the position of the rotating disc 22, for example using an oscilloscope and the tab 28, the spectral content of the radiation source 6 can be displayed. In alternative embodiments of the invention, the single detector 14 can be replaced by two or more detectors.

Referring now to Figures 4 and 5, there is shown a radiometer 20 which is like the radiometer 20 shown in Figures 2 and 3 except that in Figures 4 and 5, the radiometer 20 has a fixed exit slit 10, and the disc 22 and the aperture 24 replace the entrance slit 8. In this case, the slots 26 cause the spatially separated spectral image to be scanned repeatedly across the fixed exit slit 10. The spectral content of the radiation source 6 can be recorded as mentioned above.

Referring now to Figure 6, it will be seen that the radiometer 20 can be designed with more than one aperture 24. Figure 6 shows three apertures 24a, 24b, and 24c. These apertures, similarly to aperture 24 in Figures 3 to

5 can be placed in front of or behind the disc 22. The apertures 24a, 24b, 24c are separated normal to slots 26a, 26b, 26c in the plane of the disc 22. Thus the slots 26a, 26b, 26c scan different spectral regions. This is because, for the rotating disc 22 at the entrance slit 8, the centre of the spatially dispersed spectral images from each aperture 24a, 24b, 24c will be laterally displaced at the exit slit 10. For the rotating disc 22 at the exit slit 10, each aperture will let pass a different part of the spatially dispersed image of the slot 26a, 26b, 26c in the disc 22.

Often one output reading is required for the measurement of a radiation source 6, rather than a spectral scan. This is because the radiation source 6 is to be measured in the way that it interacts with something that responds to different wavelengths of light in a repeatable and predictable manner. For example, photometers measure light with a spectral response that matches that of the human eye. To achieve the required single output reading, the curvature of the slot 26 and the slot width can be varied along its length in order to weight parts of the scanned spectrum differently. The lower the curvature of the slot 26 and/or the wider the slot 26, then the greater the weight given to the part of the spectrum passed by the slot 26 and the aperture 24. If the detector 14 has a time constant significantly

greater than the period of rotation of the disc 22, then the time averaged recorded signal will be a weighted mean of the incident spectrum. Thus discs 22 can be designed with a slot of a geometry that achieves a desired weighted spectral response. In effect, the spectral response of the radiometer 20 is programmed by the slot shape. Known radiometers are usually detectors fitted with glass or interference filters to select a particular spectral region. These filters are often poor matches to the required response curves, for example of the human eye, and cannot be altered once the filter is made.

The output of the radiometer 20 can be digitised with an analogue to digital converter. The digitisation may be carried out over a set number of intervals for each rotation of the disc 22 generating one sequence of generised data points per rotation. Each data point in the sequence would correspond to a particular narrow spectral bandwidth of radiation. This process would be carried out synchronously with the disc rotation so that for each rotation of the disc 22 a sequence of data points is generated, each data point at the same position in the sequence corresponding to the same narrow spectral bandwidth of radiation. Thus, by adding the first, second, third etc. data points of each sequence from each rotation of the disc 22, the spectral content of the radiation source 6 is measur d. Averaging this data over

many rotations reduces the signal to noise level of the recorded spectrum. This approach to signal processing is known, for example by the known Monolight instrument specification which uses a rotating grating. The process may be carried out using a personal computer but is preferably carried out by purpose-built electronics.

Referring now to Figure 7, there is shown an illustration of a disc 22, an aperture 24 and two slots 26. It will be seen that part of the disc 22 is blank so that the aperture 24 is completely blocked at some point of the disc's rotation. This provides a zero reading. Thus a radiometer having the design shown in Figure 5 can be used to correct the recorded spectrum for zero level signals.

Another way of achieving a weighted spectral response is to include a memory to store the correct weighting function of the recorded spectral data for the particular application required. The response of the radiometer can be calculated as a function of wavelength and then the required weighting of each of the data points in the recorded sequence calculated. This weighting can then be stored electronically in the radiometer. The radiometer would then integrate the recorded data weighted by these weighting factors to generate a single value which the radiometer displays. Such an instrument is thus a programmable radiometer and

is programmable in the sense that the spectral response shape of the radiometer is set by the data set in the memory.

Referring now to Figure 8 there is shown the use of two diffraction gratings 4, two collimating mirrors 16 and two focusing mirrors 18. This is achieved by the use of the illustrated two 45 degree mirrors 30 and the exit mirrors 32. Two detectors 14 are employed adjacent two exit slits 10 as shown. Thus Figure 8 illustrates how one disc 22 can be used with two apertures 24, two diffraction gratings 4, two collimating mirrors 6, two focusing mirrors 18, two exit slits 10 and two detectors 14. Thus the radiometer 20 shown in Figure 8 is able to scan two different spectral regions simultaneously. Thus Figure 8 is a way of overcoming the fact that a particular diffraction grating 14 can only cover a limited spectral region and this problem can be overcome by placing the apertures 24 around the disc 22 and doubling up on the components as mentioned above.

If the radiation source 6 to be measured has only a limited spectral cover, for example a laser, then the digitised sequence of data can be used to calculate the mean wavelengths of the radiation source 6. This calculation may be carried out by dedicated electronics in the radiometer 20 and it may be displayed as a single

number, the average wavelength. The radiometer 22 then acts as a wavemeter.

It will be appreciated from the above description that the radiometers of the present invention are advantageous for the following reasons.

1. Traditional monochromators which scan wavelength by rotating the dispersing optical component require a very well engineered and expensive mechanism to ensure accurate knowledge of the position of the dispersing optical component and hence the wavelength set. The radiometers of the present invention provides a low cost high accuracy scanning mechanism.
2. The above mentioned Monolight apparatus using a rotating grating also provides a low cost wavelength drive. However, as the grating spins, it is only set at angles required for the collection of dispersed radiation for a small part of the rotation. This means that for much of the time, the apparatus is not collecting radiation and this leads to much smaller signals. The radiometers of the present invention collect radiation at all times except when recording at a zero radiation signal. Also, the slot or slots 26 in the disc 22 can have a variable geometry, giving more control over the wavelength scan.

3. Spectrometers with fixed gratings and detector arrays are also expensive because of the complexity of the detector design and electronic processing. Also, only a very limited range of materials are available to make detector arrays.

4. Known broadband radiometers are usually manufactured with glass or interference filters. The required spectral response shape cannot be generated accurately by this approach, especially for ultraviolet radiation. The radiometer of the present invention makes it possible to obtain a better spectral match and one that can be changed during the life of the radiometer to correct for ageing.

It is to be appreciated that the embodiments of the invention described above with reference to the accompanying drawings have been given by way of example only and that modifications may be effected. Thus, for example, the diffraction grating may be replaced by a prism or another type of dispersing optical component. The collimating and focusing mirrors 16, 18 can be combined together as one mirror. Figure 8 shows the use of two diffraction grating systems but more than two of such systems can be employed if desired, for example four such systems.

CLAIMS

1. A broadband radiometer comprising a housing, dispersing means for dispersing radiation from a radiation source such that the radiation is spatially separated into component parts of different wavelengths, entrance means for enabling radiation to enter the housing, exit means for enabling radiation to leave the housing, obturator means which is rotatable and which is for blocking the path of the radiation, at least one slot which is provided in the obturator means, an aperture which is positioned for registering with the slot and which forms the entrance means or the exit means in dependence upon the position of the obturator means, and detector means for detecting radiation passing through the slot and the aperture.

2. A broadband radiometer according to claim 1 and including electrical drive means for driving the obturator means.

3. A broadband radiometer according to claim 1 or claim 2 in which the aperture is positioned at an exit part of the programmabe broadband radiometer, whereby the aperture forms the exit means.

4. A broadband radiometer according to claim 1 or claim 2 in which the aperture is positioned at an entrance part of the broadband radiometer, whereby the aperture forms the entrance means.

5. A brodband radiometer according to any one of the preceding claims in which the obturator means is positioned in front of the aperture.

6. A broadband radiometer according to any one of claim 1 to 4 in which the obturator means is positioned behind the aperture.

7. A broadband radiometer according to any one of the preceding claims in which the obturator means is a disc.

8. A broadband radiometer according to claim 7 in which the disc is rotatable about an axis perpendicular to the plane of the disc.

9. A broadband radiometer according to any one of the preceding claims in which the slot is curved.

10. A broadband radiometer according to claim 9 in which at least one of the curvature of the slot and the width of the slot varies along the length of the slot in order

to weight different parts of the scanned spectrum differently, the lower the curvature of the slot and/or the wider the slot, the greater the weight given to the part of the spectrum passed by the slot and the aperture.

11. A broadband radiometer according to any one of the preceding claims in which the slot is interrupted in order to provide a zero reading during rotation of the obturator means.

12. A broadband radiometer according to any one of the preceding claims in which there are two or more of the slots.

13. A broadband radiometer according to any one of the preceding claims and including memory means for storing the correct weighting function of the recorded spectral data for the particular application required.

14. A broadband radiometer according to claim 13 in which the response of the broadband radiometer is able to be calibrated as a function of wavelength, and in which the required weighting of each of the data points in the recorded sequence is then able to be calculated.

15. A broadband radiometer according to any one of the preceding claims and including an analogue to digital converter.

16. A broadband radiometer according to any one of the preceding claims in which the entrance means is an entrance slit when it is not formed by the aperture.

17. A broadband radiometer according to any one of the preceding claims in which the exit means is an exit slit when it is not formed by the aperture.

18. A broadband radiometer according to any one of the preceding claims in which the dispersing means is a diffraction grating.

19. A broadband radiometer according to claim 18 and including a collimating mirror and a focusing mirror, the collimating mirror and the focusing mirror being for use with the diffraction grating in enabling the radiation to pass from the entrance means to the exit means.

20. A broadband radiometer substantially as herein described with reference to Figures 2 to 8 of the accompanying drawings.

Patents Act 19[illegible]
Examiner's report to the Comptroller under Section 17
(The Search report) -20-

Application number
GB 9310684.7

Relevant Technical Fields

(i) UK Cl (Ed.M) G1A (ACDX, AHSL, ARN)

(ii) Int Cl (Ed.5) G01J

Search Examiner
R S CLARK

Date of completion of Search
29 JULY 1994

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) ONLINE DATABASE: WPI

Documents considered relevant following a search in respect of Claims :-
1

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2230088 A	(ZARAKPATRIBOR)	1,2,7,8,9, 18
X	GB 2230087 A	(ZARAKPATRIBOR)	1,2,7,8,12, 18
X	GB 2080947 A	(VARIAN)	1,2,3,5,7, 8,11,12, 16,18,19
X	GB 809364	(HILGER & WATTS)	1,2,3,6,7, 8,11,12,16
X	GB 732058	(LEEDS & NORTHRUP) Figure 6	1,2,7,8, 12,18,19
X	GB 672758	(GOLAY)	1-8,11,12, 16-19
X	US 4448529	(KRAUSE) lines 23-44 column 5, lins 29-36 column 6, and lines 45-54 column 14	1-6,12

Databases:The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).